RESEARCH AT VATLY

N.T. THAO [*a,b], P.T. ANH[a,b], P. DARRIULAT[a], P.N. DIEP[a], P.N.DONG[a],
N.V. HIEP[a,b], D.T. HOAI[a,b] AND P.T.T. NHUNG[a]

[a]*Institute for Nuclear Science and Technology,179 Hoang Quoc Viet, Cau Giay, Hanoi*
[b]*Institute Of Physics, 10 Dao Tan, Hanoi*
Email: thao@mail.vaec.gov.vn

Abstract: *The main research activities of the Vietnam Auger Training LaboratorY are briefly reviewed. They include research on ultra high energy cosmic rays at the Pierre Auger Observatory in Argentina, research at home using scintillator and Cherenkov detectors and research in radio astronomy using our 2.6 m telescope equipped for detection of the 21 cm hydrogen line as well as interferometer arrays at the Plateau de Bure and, later on, in Chile (ALMA).*

Keywords: *Cosmic rays, Radio astronomy, VATLY*

I. INTRODUCTION

VATLY stands for Vietnam Auger Training LaboratorY. It owes its name to the Pierre Auger Observatory (PAO) in Argentina with which it is associated. Its aim is to establish in Hanoi a team of researchers of international stature having the ambition to promote in the country teaching and research in fundamental sciences, and in particular in astrophysics. It is installed in the premises of the Institute of Nuclear Sciences and Technologies (INST) in Hanoi.

The staff includes three Postdocs, two PhD students and two Master students. Research interests are the study of cosmic rays at the extreme end of the energy spectrum and, recently, radio astronomy. Much of it is made in collaboration with other institutes, using data collected by major research installations abroad. In particular most PhD theses are made under an agreement of joint supervision with prestigious foreign universities.

The laboratory is equipped with instruments that are used for training and for domestic research. We receive support from the INST/VAEI (running expenses), from the Ministry of Science and Technology (following a budget request made through Nafosted) and from various organizations in the form of fellowships (Odon Vallet, World Laboratory, etc.) or of occasional support (French CNRS/LIA, host universities/joint supervision PhD theses, Observatoire de Paris, etc.)

II. THE PIERRE AUGER OBSERVATORY (PAO)

The PAO (Figure 1) detects Ultra High Energy Cosmic Rays (UHECRs, $E>10^{18}$ eV) from the showers they produce when interacting with the earth atmosphere. The aim is to understand what they are (most likely protons or iron nuclei), where they come from and how they are accelerated. It includes an array of 1660 detectors on ground covering 3000 km^2 and 24 fluorescence telescopes.

Two major results have already been obtained [1]:

– Evidence for interaction with the cosmic microwave background producing an energy cut-off at ~10^{20} eV;

– Evidence for a correlation with active galaxies in the nearby universe, in particular with Centaurus A.

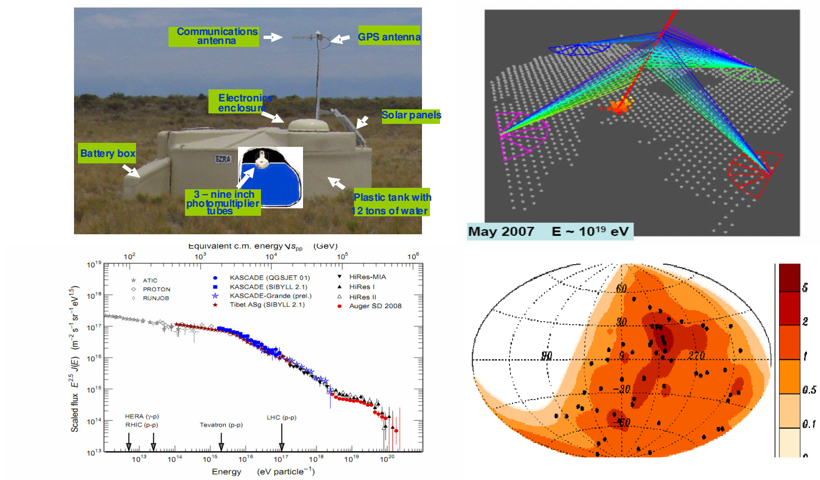

Fig. 1. The PAO. Top left: exploded view of a detector of the ground array. Top right: an hybrid event with its imprint on ground. Lower left: energy spectrum multiplied by $E^{-2.5}$ showing the GZK cut-off. Lower right: correlation between UHECRs and the density of galaxies in the nearby universe.

PAO data are dispatched to all collaborating institutions. Major VATLY contributions include:

– A study of low amplitude signals and the detection of decay electrons from stopping muons; the main value of this study is to provide evidence for the proper functioning and low noise of the detectors of the ground array and for the adequacy of its simulation (Figure 2, upper left).

– A measurement of shower divergences and of the mean altitude of the shower maximum; it uses the asymmetry measured between the signals given by the three photomultiplier tubes of each ground detector hit by the shower (Figure 2, upper right).

– Contribution to the identification of the primaries (iron or proton) from the muon density on ground; it provides a critical study of the systematic uncertainties and shows that a change of the energy scale, contrary to what had been proposed, cannot resolve the disagreement between measured and predicted densities.

– Contribution to the identification of the primaries having their sources in the Cen A region; it shows that, contrary to the original shift from proton to iron observed with increasing energy on the whole sky, Cen A showers prefer protons to iron nuclei.

– Detailed studies of the long term stability and ageing of the PAO Cherenkov detectors; they give evidence for minute seasonal oscillations (Figure 2, lower left), day/night variations, sudden jumps in particular occasions, a settling period following the filling of the detector with water, a very slow ageing (decay time ~40 years) etc.

Instabilities associated with summer storms or occurring on the occasion of sudden temperature changes and occasional trailing of the photomultiplier signals are studied in detail. Such studies are a very valuable contribution to the understanding of the ground detector.

– A study of the response of the PAO photomultiplier tubes as a function of photon impact and of the orientation with respect to the geomagnetic field (made in Hanoi); the study (Figure 3) provides evidence for a dependence that had been previously unnoticed and explains it in simple terms.

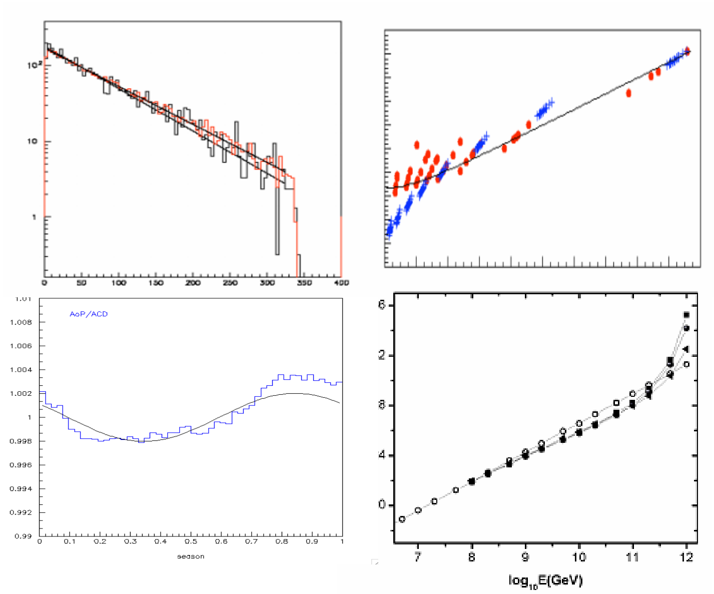

Fig. 2. Examples of VATLY contributions to the PAO. Upper left: time distribution of electron decays from data (red) and simulation (black). Upper right: altitude of mean shower vertex (km) vs radial distance (km) to shower axis as measured by asymmetry (red) and from longitudinal profile (blue). Lower left: seasonal variations of the pulse shape over one year. Lower right: depth of the shower maximum as a function of the decimal logarithm of energy (GeV) ignoring (circles) or including (squares) the LPM effect.

In relation with research at the PAO, simulation codes describing the longitudinal and transverse developments of air showers have been conceived and written at VATLY. They have allowed for studies of the Landau-Pomeranchuk-Migdal (Figure 2, lower right) and Perkins effects (quantum phenomena having macroscopic consequences at the highest energies) and are currently used to study the muon component of UHECR showers which happens not to be properly described by conventional codes. To this aim, an extensive simulation of hadronic shower development has been performed and has allowed for a parameterization of the longitudinal and transverse shower profiles as a function of altitude, energy and angle of incidence, making it possible to generate a large quantity of ultra high energy showers in a reasonable computing time.

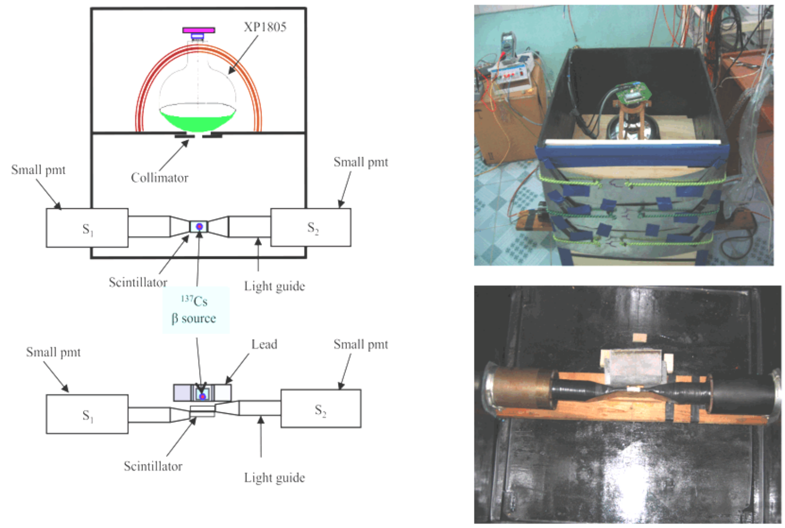

Fig. 3. Experimental arrangement used for the PAO photomultiplier studies performed in Hanoi. Light is produced by two scintillators in coincidence and a Cesium source. Mu-metal may be used to shield the PMT from the geomagnetic field.

III. RESEARCH AT HOME

The laboratory is equipped with detectors of various types meant to provide training of students and to make the research staff familiar with the tools and techniques used in larger installations. They include scintillator and Cherenkov detectors with their associated electronics, a radio interferometer and a radio telescope equipped to detect the hydrogen 21 cm line.

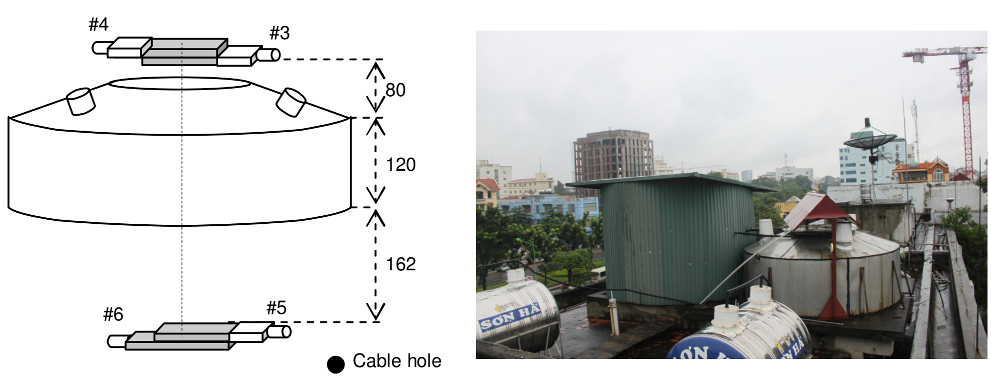

Fig. 4. The VATLY Cherenkov counter and the trigger hodoscope.

A replica of a PAO detector (Figure 4) has been constructed on the roof of the laboratory. It is used to study its properties and to make measurements of various types. A trigger provided by three smaller Cherenkov detectors surrounding it makes it possible to study extensive air showers around the TeV range. A scintillator hodoscope bracketing it from above and below is used to calibrate its response using relativistic feed-through muons. The detector is currently used to study the correlation between successive signals, allowing for a separation of two main components: muons pertaining to a same shower and decay (or capture) of stopping muons. A scintillator detector provides a reference to the water Cherenkov detector response.

A radio interferometer including two Yagi antennas has been used to detect radio emissions of the Sun around 600 MHz. Beautiful interference fringes (Figure 5) have been observed [2] with a signal to noise ratio of ~100 and a signal to background ratio of ~1%. The power density detected was measured to be 4±4 dB above that expected from the quiet sun. The detector has now been given to the Hanoi University of Education for training students.

A radio telescope (2.6 m dish) equipped for the detection of the 21 cm line (Figure 6, left) has been recently installed on the roof of the laboratory. Detection of the hydrogen in the Milky Way, Doppler measurement of the Galaxy rotation, observation of the arm structure of the Galaxy, of solar activity over a full rotation cycle and of various strong radio sources (Cen A, Andromeda, Cassiopea, Sgr A*) are within reach. A typical spectrum is shown in Figure 6 (right).

Finally, a collaboration has been established with the Observatoire Midi-Pyrenees to analyse millimetric data collected at the radio telescope array of Plateau de Bure in the framework of a PhD thesis (joint supervision).

We are also training undergraduate students who spend four to six months with us to work on their dissertation at the end of their university years.

The four most recent studies were:

- Global warming and cosmic rays [3],
- A study of diffusive shock acceleration in young Supernova remnants [4],
- The three body problem and formation of X-ray active binaries by capture,
- Gravitational lensing and Einstein rings.

Solar interferences: one day of measurement, each panel is for 1000 seconds. The line is the result of a global fit.

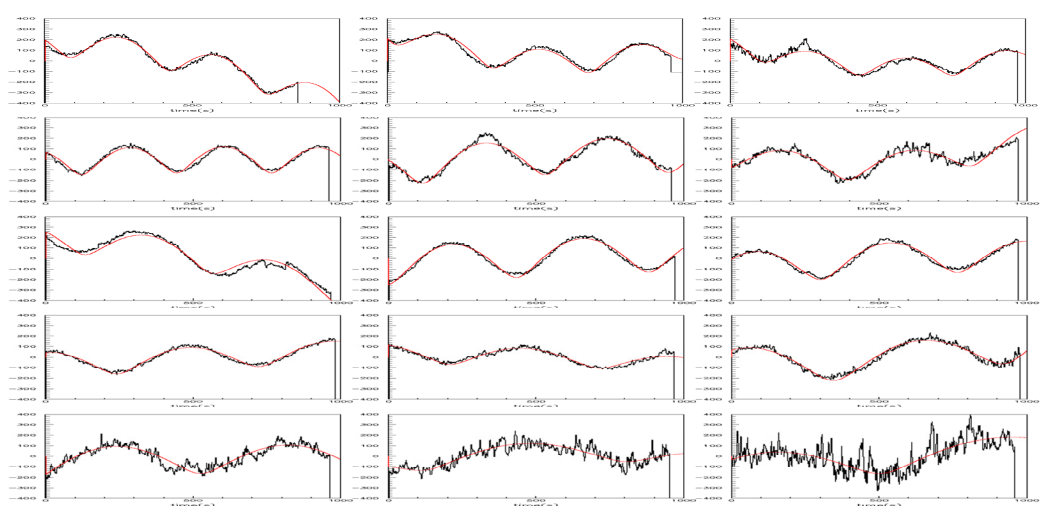

Fig. 5. Measured solar interference fringes and result of the best fit (red lines).

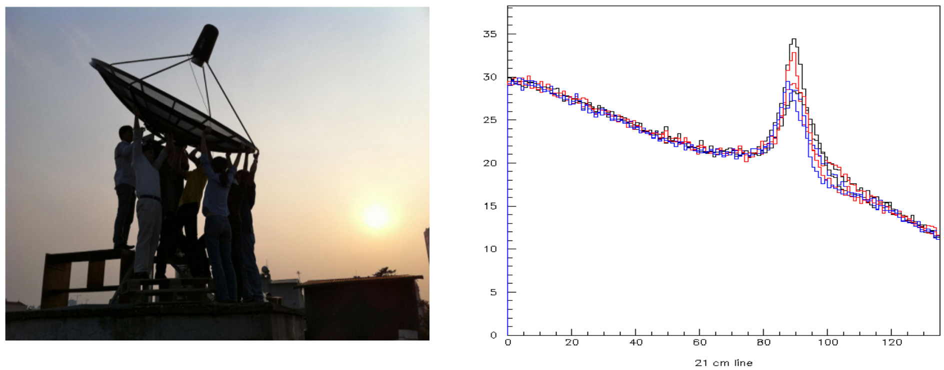

Fig. 6: Small radio telescope on the roof of VATLY (left) and the 21 cm hydrogen line measured in the center of the Milky Way (Sgr A) (right).*

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[5] VATLY publications are listed on our website, http://www.inst.gov.vn/Vatly/publications.htm